

Articles

How Well Do Older Persons Tolerate Moderate Altitude?

ROBERT C. ROACH, PhD, *Albuquerque, New Mexico, and Keystone, Colorado;*

CHARLES S. HOUSTON, MD, *Keystone, Colorado, and Burlington, Vermont;*

BENJAMIN HONIGMAN, MD, RICHARD A. NICHOLAS, MD, *and*

MICHAEL YARON, MD, *Keystone and Denver, Colorado;* COLIN K. GRISSOM, MD, *Seattle, Washington;*

JAMES K. ALEXANDER, MD, *Keystone, Colorado, and Houston, Texas; and*

HERBERT N. HULTGREN, MD, *Keystone, Colorado, and Stanford, California*

We studied the physiologic and clinical responses to moderate altitude in 97 older men and women (aged 59 to 83 years) over 5 days in Vail, Colorado, at an elevation of 2,500 m (8,200 ft). The incidence of acute mountain sickness was 16%, which is slightly lower than that reported for younger persons. The occurrence of symptoms of acute mountain sickness did not parallel arterial oxygen saturation or spirometric or blood pressure measurements. Chronic diseases were present in percentages typical for ambulatory elderly persons: 19 (20%) had coronary artery disease, 33 (34%) had hypertension, and 9 (9%) had lung disease. Despite this, no adverse signs or symptoms occurred in our subjects during their stay at this altitude. Our findings suggest that persons with preexisting, generally asymptomatic, cardiovascular or pulmonary disease can safely visit moderate altitudes.

(Roach RC, Houston CS, Honigman B, et al: How well do older persons tolerate moderate altitude? *West J Med* 1995; 162:32-36)

In recent years more and more older men and women have sojourned at moderate altitudes—2,000 to 3,000 m (6,500 to 9,800 ft)—for recreation or work, but little attention has been given to the effect of age or existing disease on their tolerance for altitude. Older visitors might be expected to be at greater risk for acute mountain sickness (AMS) because of underlying cardiovascular or pulmonary disease or the normal processes of aging. They might also risk exacerbation of their underlying diseases. Although this risk appears to be small,^{1,3} practicing physicians have little data on which to base advice to their older patients. We studied a group of older men and women visiting a mountain resort at 2,500 m (8,200 ft) to determine their susceptibility to AMS and to examine their cardiovascular and pulmonary physiologic responses and clinical signs and symptoms over a five-day period at moderate altitude.

Study Group and Methods

We randomly selected 105 persons from the first 500 men and women who registered for the 50th reunion of the United States Army Tenth Mountain Division in Vail, Colorado (altitude 2,500 m). The reunion site was chosen because of its proximity to Leadville, Colorado,

and the former location of Camp Hale, where the Tenth Mountain Division trained during World War II. Of the 105 men and women, 8 were excluded because of scheduling conflicts or incomplete data, leaving 97 for study. No one was excluded for reasons of health. All signed informed-consent forms approved by the Colorado Multiple Institutes Review Board of the University of Colorado Health Sciences Center, Denver.

Data Collection

Before they arrived in Vail, subjects completed a questionnaire that included the altitude of their residence; their history of hypertension, heart or lung disease, diabetes mellitus, or smoking; their usual exercise pattern; and their self-rated fitness. On arrival in Vail (day 0), participants were briefed and given a questionnaire on activities, symptoms of AMS, and other health-related symptoms. These same questions were answered each day of the study. Symptom scores for AMS were tabulated using graded (0 to 3) self-evaluation of headache, sleeplessness, fatigue, light-headedness, and gastrointestinal symptoms; AMS was defined as a score of 3 or higher, including at least one point for headache.⁴ Subjects were then asked if they had had any of the fol-

From the Lovelace Institute for Basic and Applied Medical Research, Albuquerque, New Mexico (Dr Roach); the Department of Medicine, University of Vermont, Burlington (Dr Houston); the Colorado Altitude Research Institute, Keystone (all authors); the Division of Emergency Medicine, Colorado Emergency Medicine Research Center (Drs Honigman and Yaron), and the Department of Family Medicine, University of Colorado Health Sciences Center (Dr Nicholas), Denver; the Department of Medicine, University of Washington School of Medicine, Seattle (Dr Grissom); the Department of Cardiology, Baylor College of Medicine, Houston, Texas (Dr Alexander); and the Division of Cardiovascular Medicine, Stanford University School of Medicine, Stanford, California (Dr Hultgren).

Reprint requests to Robert C. Roach, PhD, Lovelace Institute for Basic and Applied Medical Research, 2425 Ridgecrest SE, Albuquerque, NM 87108.

ABBREVIATIONS USED IN TEXT

AMS = acute mountain sickness
 ANOVA = analysis of variance
 ECG = electrocardiogram
 Sao₂ = arterial oxygen saturation

lowing during the previous 24 hours: difficulty breathing, palpitations, or chest pain. If they had, they were asked whether these affected their activity and if they took medications for relief. The final question was how many alcoholic drinks were consumed in the past 24 hours. On day 0, we asked about previous altitude exposure and altitude illness. We also maintained logs at the local hospitals and physician offices to determine if any of our subjects required medical attention.

Beginning on day 1, those studied reported to one of six identical stations for testing on each of the first three days (days 1 to 3) and again on either the fourth or fifth day (recorded as day 4). After completing the daily questionnaire, participants rested supine for four minutes before a 12-lead electrocardiogram (Marquette, Model #MAC PC), blood pressure (Colin Medical Instruments Model BP-8800p), pulse rate, and arterial oxygen saturation (Sao₂; Ohmeda Model #3700 pulse oximeter) were recorded. Blood pressure, pulse rate, and Sao₂ measurements were repeated a minute later, and the two readings were averaged. Electrocardiograms were read independently by each of two cardiologists and assessed for abnormalities and changes from tracings taken in Vail on previous study days. Abnormalities were defined according to the Minnesota code.⁵

Pulmonary function was assessed using identical electronic spirometers (Spirometric Flowmate II) that were calibrated twice a day. After cardiovascular measurements were completed, those studied were seated, with nose clips in place; repeated measurements were

made, and the best of at least three attempts was recorded. Measurements included forced vital capacity (% predicted⁶), one-second forced expiratory volume (% predicted⁶), and peak expiratory flow (liters per minute).

Medical histories, historical heart rate, blood pressure values, and ECGs were requested retrospectively from the personal physicians of those studied. The presence of underlying long-term diseases was determined by these reports and verified by physician questionnaire in 98% of those studied. Data were reported using the self-reports. If a discrepancy existed, the physician questionnaire was used.

Statistical Analyses

Data were analyzed using repeated measures of analysis of variance (ANOVA) for analysis of day-to-day changes and two-way ANOVA for an analysis of changes between groups such as normotensive and hypertensive subjects. Post hoc pairwise comparisons were made using Tukey's post hoc test. Data are presented as the mean plus or minus the standard error of the mean (SE). A *P* value of less than .05 was considered significant.

Results

Of the 97 participants aged 69.8 (± 0.5 years; range, 59 to 83), 77 (79%) were men, and 81 (84%) lived at or near sea level. The characteristics of the study group are reported in Table 1. Of note, 19 (20%) of the participants had coronary artery disease, 33 (34%) had hypertension, 9 (9%) had lung disease, and 5 (5%) had diabetes mellitus. Of those studied, 76 (78%) considered themselves to be in good to excellent physical condition; 88 (91%) described themselves as moderately to very active before this visit, and the rest were usually inactive at home. Before arriving in Vail, 73 (75%) had stopped for 24 to 48 hours at a lower altitude (average elevation, 1,600 m [5,250 ft]), 22 (23%) had not stopped at an intermediate altitude, and 2 (2%) had stopped above 2,500 m (8,200 ft).

Incidence of Acute Mountain Sickness

Of the 97 persons studied, 16 (16%) had AMS at some time during their stay in Vail; for 11 of the 16, AMS occurred on day 0 or the next day. The remaining 5 cases occurred in the next two days. Acetaminophen or aspirin was used by 8 of the 16 with AMS; 1 took a sleeping pill to relieve symptoms. Of those with AMS, all had previously been to high altitude, and 7 had previously experienced altitude illness. Alcohol intake was not related to the incidence or severity of AMS. In fact, the 81 who did not have AMS had a greater alcohol intake than those who did (*P* < .05). Activity was mildly to moderately reduced in 8 of those with AMS and not at all in the remaining persons studied.

Of those who did not meet the criteria for AMS, 66 had no symptoms of altitude illness, 10 had one symptom, and 5 had two symptoms attributable to altitude. All but one had previously been to altitude, and 10 had

TABLE 1.—Subject Characteristics (mean ± SE) and Health History Provided by Personal Physicians

Characteristic	Subjects		US Population*
	Men (n=77)	Women (n=20)	
Age, yr	70.7±0.5	66.7±1.1	32
Height, cm.....	175.6±0.8	163.6±2.0	
Weight, kg.....	82.6±1.5	69.9±3.3	
	No. (%)	No. (%)	%
Cardiovascular	19 (25)	0 (0)	27
Hypertension.....	27 (35)	6 (30)	37
Pulmonary.....	8 (10)	1 (5)	
Diabetes mellitus†	5 (6.5)	0 (0)	10
Current smokers.....	14 (18)	5 (25)	16
Former smokers.....	52 (67)	9 (44)	68
Self-assessed fitness			
Excellent.....	17 (22)	5 (25)	37
Good.....	44 (57)	10 (50)	32
Fair/poor	16 (21)	5 (25)	31

*From US National Center for Health Statistics, Vital and Health Statistics, Series 10, 1990.

†Taken from self-report questionnaire.

previously experienced altitude illness. Of those studied, 10 reported a mild reduction in activity because of their symptoms, and 9 took acetaminophen or aspirin for their symptoms.

At some time during their stay in Vail, 36 of the 97 persons studied (37%) had mild difficulty breathing; 23 (24%) had palpitations; and 11 (11%) had nonspecific chest pain. None of these symptoms were related to AMS or were severe enough to require medical attention.

Arterial Oxygen Saturation

The daily Sao_2 was $92\% \pm 0.1\%$ over the five days at altitude, with less than 1% daily variation (Figure 1-A). Although the Sao_2 was not statistically different between those with and those without AMS ($P = .15$), there was a slight rise in the Sao_2 over the four days in those free of AMS and a slight fall in Sao_2 in those with AMS.

Spirometry

Forced vital capacity (% predicted) increased from day 1 on days 2 and 4 ($P < .01$) and showed the same trend on day 3 (Figure 1-B). Other spirometric measurements did not change over the time in Vail. For all those studied over the five days at Vail, the one-second forced expiratory volume was $91\% \pm 1\%$ of predicted and the mean peak expiratory flow was 7.1 ± 0.1 liters per minute.

Cardiovascular Observations

On the subjects' arrival at Vail, electrocardiogram (ECG) results were normal in 59 (61%). In the remain-

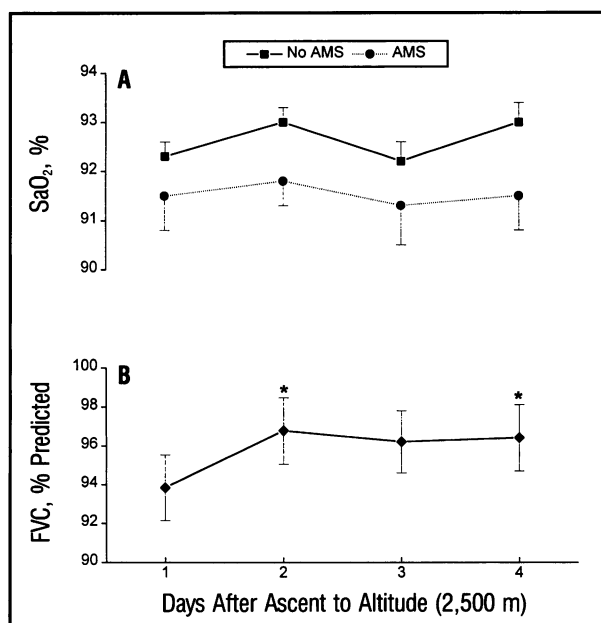


Figure 1.—A, The arterial oxygen saturation (Sao_2) in elderly visitors to moderate elevations (2,500 m [8,200 ft]) over a 5-day period in those with acute mountain sickness (AMS) is compared with Sao_2 values of those without AMS. Between-group differences were not statistically significant. B, A slight increase occurred in the forced vital capacity (FVC) in all subjects on days 2 and 4 ($P < .01$).

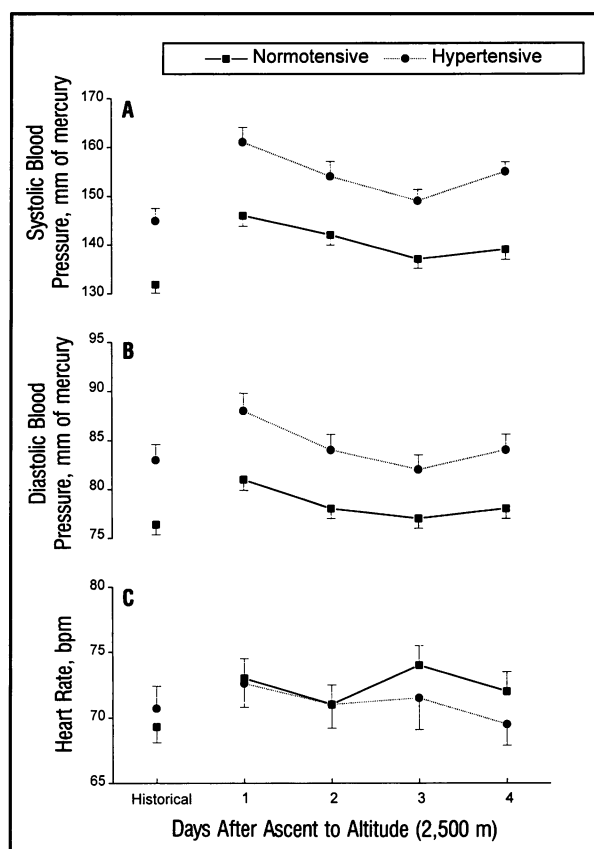


Figure 2.—A, Systolic and, B, diastolic blood pressure and, C, heart rate responses are shown in hypertensive and normotensive subjects on days 1 through 4 at 2,500 m (8,200 ft). Blood pressures decreased significantly on all days compared with day 1 ($P < .01$) in both hypertensive and normotensive subjects and were significantly higher on all days in the hypertensive group compared with the normotensive group ($P < .001$). Historical blood pressure values from each patient's physician ($n = 95$) are shown for comparison.

ing 38, a wide variety of abnormalities were noted; 19 (20%) had ECG abnormalities suggestive of coronary artery disease. These included Q waves, ST depression, left bundle branch block, and left anterior fascicular block. No clinically important changes were noted during serial ECG measurements in any of our subjects during their stay in Vail.

Of the 38 participants with ECG abnormalities identified on their arrival in Vail, previous ECGs were obtained from 21. Of these, 17 showed no changes between their historical ECGs and the ones taken in Vail. Of the remaining 4 participants, altitude ECG tracings in 2 revealed minor ST segment depression consistent with ischemia, and in the other 2 persons studied, atrial fibrillation was present. The importance of the changes from the historical records in these four is unclear because the ECG tracings before ascent were obtained one to three years before their arrival in Vail. No symptomatic events occurred in these four that indicated the presence of myocardial ischemia.

Apparently both systolic and diastolic pressures were increased on day 1 in Vail and then declined progressively over subsequent days at altitude in both normotensive and hypertensive persons studied (Figure 2-A and -B, $P < .01$). We obtained historical blood pressure values on 95 of the 97 participants. These values, predominantly from near sea level, were significantly lower than the day 1 values for both groups at Vail ($P < .05$, Figure 2-A and -B). When or under what conditions participants' blood pressure measurements were obtained by their physicians is not known. Heart rates did not differ significantly between hypertensive and normotensive groups and did not change over time in Vail. Of the 33 persons with hypertension, 28 were taking some combination of antihypertensive medication; only 1 is known to have increased his dose of antihypertensive medication while at Vail. The 5 with hypertension but not on a medication regimen maintained their blood pressures within normal values throughout their stay in Vail.

Of note, four participants with hypertension had systolic pressures above 180 mm of mercury or diastolic pressures above 110 mm of mercury on either day 0 or 1. In these four, the systolic pressure fell from 197 ± 7 mm of mercury on day 1 to 167 ± 5 mm of mercury (SE) on day 4, and the diastolic pressure fell from 101 ± 9 mm of mercury to 90 ± 6 mm of mercury ($P < .01$). Three other persons studied, not known to have hypertension, had systolic pressures above 180 mm of mercury on the first two days of the study; in all three, the pressure decreased to below 180 mm of mercury by day 3.

Discussion

This study represents to date the most comprehensive investigation of older persons visiting moderate altitude. The most important observation in this group is that active travelers with preexisting asymptomatic cardiovascular and pulmonary disease safely traveled to moderate altitudes without exacerbation of their disorders. Our data also suggest that the incidence of AMS was not higher in this group than in younger persons.

The 16% incidence of AMS in this group of older persons was slightly lower compared with previous reports on younger persons.^{7,9} In fact, the symptoms were less severe and had less effect on the activities of those studied than expected from previous reports in younger persons.^{7,8} Several factors may have influenced the lower incidence of AMS in our study. A brief stopover at a lower altitude may have contributed, although it has been shown that a stay of less than 38 hours has little effect.⁸ Also, older persons tend to minimize their symptoms when completing a questionnaire.¹⁰ Finally, our group might have been self-selected in that they felt able, based on previous experience, to go to this altitude. Nevertheless, the health history of this group is similar to that of other groups that visit similar altitudes for meetings and conferences, and we consider our findings applicable to the older traveling public.

In our previous study, we found that 16% of 410 visitors to moderate altitudes aged 60 to 87 had symptoms

of AMS; the incidence of symptoms decreased linearly with increasing age.⁸ This finding supported that of an earlier report that showed decreased severity of AMS with increased age in 278 trekkers studied at 4,243 m (13,920 ft) in Nepal.¹¹ In a study at altitudes comparable to Vail's, 25% of 454 health professionals (ages not given) visiting two mountain resorts at 2,100 m (6,890 ft) had symptoms of AMS at some time during the five days after arrival.⁹ From these studies, we conclude that increasing age is associated with less severe symptoms of AMS.

Previous studies have suggested that older persons would show arterial oxygen desaturation and concomitant clinical signs and symptoms with exposure to high altitudes. One such study, conducted on the same six men 35 years apart, showed an increased alveolar-arterial oxygen gradient at altitudes above 3,100 m (10,170 ft).¹² Results from pulse oximetry showed that our participants were well oxygenated, however, and the results compared favorably with those from permanent, older residents at similar altitude.¹³

We found no important relationship between decreased pulmonary function and symptoms of altitude illness. In contrast, decreased vital capacity, assumed to be indicative of pulmonary interstitial edema, has been reported in young, healthy visitors to altitude ill with AMS at higher altitudes.¹⁴⁻¹⁶ The gradual increase in forced vital capacity that we observed over time in Vail was noted by others.¹⁷ A gradual increase in forced vital capacity was reported in four persons studied over seven days at 4,340 m (14,240 ft). These findings suggest that in the present study, pulmonary function was maintained and detrimental changes associated with higher altitudes were avoided.^{14,15,17,18}

The prevalence of coronary artery disease in our group was estimated to be 20%. Despite the large amount of underlying cardiovascular disease, no adverse cardiovascular symptoms occurred as a result of exposure to moderate altitude. The apparently low risk of cardiovascular complications is supported by others¹⁸⁻²¹ and by the advice that "going up into the mountains to trek or ski cross country is a safe undertaking for those who believe they are able to do this."

In previous studies, both systolic and diastolic blood pressures were increased after abrupt ascent to high altitudes in normotensive and hypertensive persons, but studies have been limited to younger persons.² Concern has been expressed that older persons who have a higher incidence of hypertension might be at greater risk at altitude.² In contrast to a previous study at a higher altitude that showed that diastolic pressures are elevated for many days after ascent,¹⁶ we found a decrease after 24 hours, although both systolic and diastolic pressures remained above historical sea level values throughout the stay at altitude.

Conclusions

It is generally safe for older men and women, including those with underlying asymptomatic heart and lung

disease, to make short visits to moderate altitudes. Asymptomatic coronary artery disease, hypertension, or pulmonary disease were not exacerbated in a clinically important way, did not result in adverse medical consequences, and did not limit the activity of the persons in our study. We suggest that hypertension is not a contraindication for visiting moderate altitudes; however, blood pressure should be monitored and antihypertensive medication regimens at sea level should be maintained. The incidence of AMS is certainly not higher than in younger persons and may be lower. Age alone is not a contraindication for a short visit to moderate altitude.

Acknowledgment

We gratefully acknowledge the enthusiastic participation of members of the Tenth Mountain Division attending their 50th reunion in 1992. Jerilu Atkins planned the logistics and participated in the study, and Chip Woodland, MD, Jill Beyer, MD, and Erica Perkins provided support. The Aspen Foundation, the Summit Foundation, the Vail Valley Foundation, the Tenth Mountain Foundation, and several other persons provided funding for this study. Marquette Electronics (Milwaukee, Wisconsin), Colin Medical Instruments (San Antonio, Texas), Spirometrics (Auburn, Maine), Graphics Control (Tustin, California), and Ohmeda (Louisville, Colorado) generously lent us their equipment.

REFERENCES

1. Graham WG, Houston CS: Short-term adaptation to moderate altitude—Patients with chronic obstructive pulmonary disease. *JAMA* 1978; 240:1491-1494
2. Hultgren HN: Effects of altitude upon cardiovascular diseases. *J Wilderness Med* 1992; 3:301-308
3. Rennie ID: Will mountain trekkers have heart attacks? (Editorial) *JAMA* 1989; 261:1045-1046
4. Roach RC, Bärtsch P, Oelz O, Hackett PH: The Lake Louise acute mountain sickness scoring system. In Sutton JR, Houston CS, Coates G (Eds): *Hypoxia and Molecular Biology*. Burlington, Vt, Queen City Press, 1993, pp 272-274
5. Blackburn H, Keys A, Simonson E: The electrocardiogram in population studies—A classification system. *Circulation* 1960; 1:147-153
6. Crapo RO, AH Morris, RM Gardner: Reference spirometric values using techniques and equipment that meet ATS recommendations. *Am Rev Respir Dis* 1981; 123:659-664
7. Dean AG, Yip R, Hoffman RE: High incidence of mild acute mountain sickness in conference attendees at 10,000 feet altitude. *J Wilderness Med* 1990; 1:86-92
8. Honigman B, Theis MK, McLain J, et al: Acute mountain sickness in a general tourist population at moderate altitudes. *Ann Intern Med* 1993; 118:587-592
9. Montgomery AB, Mills J, Luce JM: Incidence of acute mountain sickness at intermediate altitude. *JAMA* 1989; 261:732-734
10. Lowenstein S, Schrier RW: Social and political aspects of aging—Pulmonary function and disease in the elderly. In Schrier RW (Ed): *Clinical Internal Medicine in the Aged*. Philadelphia, Pa, WB Saunders, 1982, pp 1-23
11. Hackett PH, Rennie ID, Levine HD: The incidence, importance, and prophylaxis of acute mountain sickness. *Lancet* 1976; 2:1149-1154
12. Terman JW, Newton JL: Changes in alveolar and arterial gas tensions as related to altitude and age. *J Appl Physiol* 1964; 19:21-24
13. Sorbini CA, Grassi Z, Solinas E, Muiese G: Arterial oxygen tension in relation to age in healthy persons. *Respiration* 1968; 25:3-13
14. Anholm JD, Houston CS, Hyers TM: The relationship between acute mountain sickness and pulmonary ventilation at 2,835 meters (9,300 feet). *Chest* 1979; 75:33-36
15. Larson EB, Roach RC, Schoene RB, Hornbein TF: Acute mountain sickness and acetazolamide—Clinical efficacy and effect on ventilation. *JAMA* 1982; 288:328-332
16. Kamat SR, Banerji BC: Study of cardiopulmonary function on exposure to high altitude—Acute acclimatization to an altitude of 3,500 to 4,000 meters. *Am Rev Respir Dis* 1972; 106:404-413
17. Tenney SM, H Rahn, RC Stroud, JC Mithoefer: Adaptation to high altitude—Changes in lung volume during the first seven days at Mount Evans, Colorado. *J Appl Physiol* 1953; 5:607-613
18. Dill DB, Hillyard SD, Miller J: Vital capacity, exercise performance, and blood gases at altitude as related to age. *J Appl Physiol* 1980; 48:6-9
19. Grover RF, Tucker CE, McGroarty SR, Travis RR: The coronary stress of skiing at high altitude. *Arch Intern Med* 1990; 150:1205-1208
20. Halhuber M, Humpeler E, Inama K, Jungman H: Does altitude cause exhaustion of the heart and circulatory system? In Rivolier J, Cerretelli P, Foray J, Segantini P (Eds): *High Altitude Deterioration*. Basel, Switzerland, Karger, 1985, pp 192-202
21. Shlim DR, Gallie J: The causes of death among trekkers in Nepal. *Int J Sports Med* 1992; 13(suppl 1):S74-S75